A DEFINITION OF MALARIA CONTROL[1]

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Definitions primarily do not provide new information. However, they can delineate clearly the essential attributes of a subject and be regarded as postulates which must be tested by observation and altered, if necessary, and in this way furnish new information. They can sometimes, by restatement only, shift the emphasis from one attribute to another and in that way bring out an entirely new viewpoint that was formerly obscure. Definitions can also serve as first principles and provide a guide when new ideas are explored or new methods and techniques are examined.

In this heyday of malaria, when such an organized, intensive and coordinated attack on this disease is being carried on by so many individuals and organizations in some many different directions, it might be worth-while to reconsider or review critically the fundamental concepts underlying the propagation of this world-wide malady. Let us attempt to define malaria precisely, set limits or boundaries from our accumulated findings and, from the built-up framework of the problem, attempt to acquire a new viewpoint or find a new approach as was suggested by a group of distinguished malariologists who met in Atlanta in May, 1940, at the invitation of the Surgeon General of the U. S. Public Health Service. In their published report (1940) they state in part:

"While the discoveries of Laveran and Ross clarified many of the epidemiological characteristics of malaria and gave a scientific basis to what was previously empirical methods of control, it must be confessed that as yet they have not resulted in any fundamentally new approach to the problem. The accomplishments of subsequent research have largely effected refinements of details or improvements in technique without the discovery of new methods of approach. Furtherfore, is hardly seems likely that new methods will be developed until new and hitherto unknown viewpoints are acquired. Consequently there is great need to intensify research on the fundamental aspects of malaria."

Let us go back to the malaria of Ronald Ross (1910) and let us examine, in the light of our new knowledge, wider perspective and changed conditions, the premises on which malaria transmission is

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postulated. Let us precisely define malaria control in the terms and factors involved in malaria transmission.

While examining Ross' ideas, it might be well to keep in mind the remarks of Karl Pearson (1906) who wrote:

"In dealing with any natural phenomenon — especially one of a vital nature, with all the complexities of living organisms in type and habits—the mathematician has to simplify the conditions until they reach the attenuated character which lies within the power of his analysis . . . . All the mathematician can do is to make an idealized system, which may be dangerous, if applied dogmatically to any particular case, but which can hardly fail to be suggestive, if it be treated within the limits of reasonable application."

Factors Involved in Malaria Transmission

Let us take for consideration a rural area containing a certain number of people, some of whom have been infected with malaria parasites, and assume that in certain number of the infected people the malaria parasites have developed to the stage that a biting mosquito becomes infected. Also, let us assume that the area contains mosquito-breeding areas and an adult mosquito population and note that *malaria transmission is not a continuous phenomenon,* due to the nocturnal habits of the mosquito. At night the mosquito is on the wing, blood meals are obtained, and if malaria transmission is possible, it occurs at this time. During the day the whole picture becomes static; the mosquito is immobile in its secluded resting place; no biting occurs, and there is no malaria transmission. We could get some idea of what happened at night if on the next day when conditions were static we could count, examine, and allocate all the mosquitoes present in the area.

Let us make the following denotations in a manner similar to Ross:

Let $p =$ the total human population in the area.

$m = \dfrac{\text{number of malaria-infected persons}}{\text{total population}}$ the proportion of the number of malaria-infected persons to the total population, p; m is a fraction varying from zero to 1, since the number of malaria-infected persons may vary from zero to p, the total human population.

$mp =$ the number of malaria-infected people. A blood film survey would give an indication of the value of mp.

$i = \dfrac{\text{number of malaria-infectious persons,}}{\text{number of malaria-infected persons}}$ — the proportion cf the number of persons having gametocytes in their peripheral blood to the number of malaria-infected people; *i* is a fraction varying from zero to 1, since the number of malaria-infectious persons may vary from zero up to *mp*, the total number of malaria-infected people.

imp = the total number of malaria-infectious persons; persons with gametocytes in their peripheral blood. Blood slides would also indicate this quantity.

a = number of female vector mosquitoes per person.

ap = the total number of female vector mosquitoes.

b = the biting rate, the ratio of the number of mosquitoes engorged with human blood during a single night to the total female vector mosquito population, *ap; b* may vary from zero to 1, since the number of female vector mosquitoes biting humans may vary from zero to *ap;* the total female vector mosquito population. Precipitin tests would indicate the value of *b.*

s = the ratio of the number of infectious mosquitoes to the number of infected mosquitoes — the ratio of the number of infected mos quitoes which live long enough to mature the parasite to the number of infected mosquitoes. Dissection of mosquito glands would indicate the value of *s.*

baimp = the total number of infected mosquitoes.

sbaimp = the total number of infected mosquitoes with mature parasites and capable of transmitting malaria.

sb^2aimp = the total number of people who are bitten by infected mosquitoes with mature parasites

$b^2sia(1\text{-}m)mp$ = the number of new cases of malaria.

Let us take this expression for new cases of malaria and let it equal one new case of malaria, and then vary the factors and determine their limiting values for a single new case of malaria. These limiting values might be used as criteria for adequate control, as values for the factors which are less than the limiting values will not allow transmission of malaria.

Take the case where *m*, the proportion of malaria infected people, is varied; *b*, the biting rate, *s*, the sporozoite rate, and *p*, the number of people, are held constant; and determine the limiting values for *a*, the mosquito population. Keeping Pearson's (1906) remarks in mind:

Let $b^2sia(1\text{-}m)mp = 1$

$$\text{then } a(b^2sip) = \frac{1}{(m\text{-}m^2)}$$

$$\text{let } (b^2sip) = K \text{ a constant}$$

$$\text{and } aK = \frac{1}{(m\text{-}m^2)}$$

Substituting values of from 0 to 1.0 for *m* (proportion of persons infected with malaria) in the above equation, we obtain the figures given in table 1 and the curve shown in figure 1. This U-shaped curve is an equilateral hyperbola which approaches the lines $m = 0$ and $m = 1$ as its asymptotes. When the malaria rate is extremely low, a very large number of mosquitoes are required to produce one new case of malaria; also, when the malaria rate is extremely high, large numbers of mosquitoes are necessary to produce a new infection. With a malaria rate of $m = 0.001$ or 0.999, other conditions being equal, the chances for the development of a new infection are equal. For example, in a community of 1,000 people, if only one person is malaria-infected or if 999 are infected, a very large number of mosquitoes are necessary for the development of a new case of malaria.

Table 1 — Calculated value of $a\ (b^2sip)$ or aK for various values of m, (proportion of persons infected with malaria) as used for curve in Figure 1.

m	m^2	$m\text{-}m^2$	$a(b^2sip)$
1.0	1.0	0	∞
.99	.9801	.099	101
.975	.9506	.0244	41.03
.95	.9025	.0475	21.05
.925	.8556	.0694	14.4
.90	.81	.09	11.1
.85	.72	.13	7.85
.80	.64	.16	6.25
.70	.49	.21	4.76
.60	.36	.24	4.17
.50	.25	.25	4.00
.40	.16	.24	4.17
.30	.09	.21	4.76
.20	.04	.16	6.25
.15	.0225	.1275	7.85
.10	.01	.09	11.1
.075	.0056	.0694	14.4
.05	.0025	.0475	21.05
0.25	.0006	.0244	41.03
.01	.0001	.0099	101
0	0	0	∞

For values of m (proportion of malaria infected persons) from 0.1 to 0.9, aK (mosquitoes per person times a constant) varies but little, from 4.00 to 11.1, and consequently a (mosquitoes per person) varies but little. Because only a minimum number of mosquitoes per person are required to spread the infection to previously uninfected persons, when $m = 0.5$ (50 per cent of the people infected), medication or other means to lower m (the proportion of persons infected with malaria) would appear, according to figure 1, to actually increase the number of new cases of malaria, unless aK, (mosquitoes per person times a constant) was less than 4.

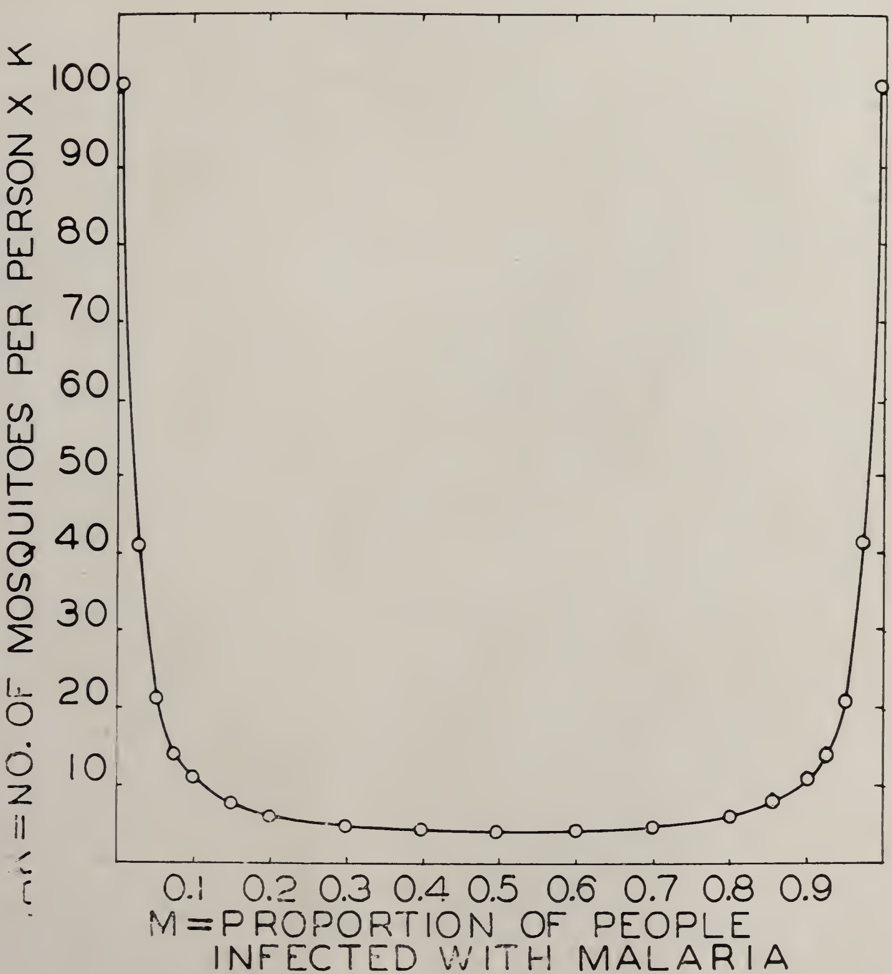

Figure 1. *Relation between number of mosquitoes and malaria incidence*

For values of m between 0.1 and 0.5, a reduction in m will reduce the chances for new cases occurring only if the values of aK are sufficiently low, from 11.1 to 4.0. The curve in this region is relatively flat, and any decrease in m produces but little reduction in aK.

However, between $m = 0.1$ and 0 and between $m = 0.9$ and 1.0 the curve becomes very steep so that a minute change in m will result in large variations in aK. The proportion of persons infected with malaria, m, is so low in this country that a small reduction in that proportion would mean that many more mosquitoes per person (much larger value of a) would be necessary to produce a single new case; therefore, control measures necessary to limit the adult mosquito population to this larger value, where no new cases would occur, could be greatly reduced.

The reverse is also true, and it is pertinent at this time when malaria-infected soldiers have returned to their homes. A slight increase in m (ration of infected persons) will greatly reduce the values of aK (mosquitoes per person times a constant) for the condition of non-transmission, and consequently increase the amount of control necessary. Such control measures should be maintained that would allow an adequate safety factor in values for aK; for example, for $m = .01$ the limiting value of aK is 101. If aK was held at 90, there would be no-transmission of malaria; however, if m is increased to 0.02 by the introduction of new cases, the corresponding aK becomes 75, and according to the curve new malaria cases would develop. However, if the adequate safety value for aK was held at 70, then a change in m from .01 to .02 would not produce malaria transmission.

The ordinate in figure 1 is the number of mosquitoes per person necessary for the production of a single new case of malaria multiplied by the factor $K = b^2sip$, so that the actual value of aK depends on the factors, b^2, the biting rate squared, s, the sporozoite rate, i, the proportion of infectious people among the infected, and p, the number of people. From these considerations one can readily see that the number of mosquitoes is not the only factor in malaria transmission and that any attempt to correlate a, the number of mosquitoes, with malaria transmission, without allowances for the other factors of equal weight, will fail. Hackett (1940) had something like this in mind when he stated: "In summing up, I would like to point out that startling failures in correlation between anopheline density and malaria prevalence in many areas have usually been explained vaguely and without proof as due to a hypothetical

'resistance to infection' built up in the population as a result of a high standard of living, reflected in better nutrition, better housing and better medical care. We must seek gradually to substitute for this easy generalization an orderly accumulation of data on factors which have hitherto escaped measurement but which must be influencing transmission in varying degree everywhere."

Factors Involved in Malaria Control

The lowest point on the curve in figure 1 occurs at m (proportion of infected persons) $= 0.5$ where aK (mosquitoes per person times a constant $= 4.0$ This is the lowest possible value of aK for the transmission of a single new case of malaria. In certain regions this value of $aK = 4.0$ might serve as a criterion for successful control. In this country where m is much less than 0.5 the value of aK could be larger. An adequately safe value of aK for any particular region will depend on the existing or potential value of m of the region under study.

The problem of malaria control is the problem of reducing the existing value of $aK = ab^2sip$ to an adequately safe value — a value for which malaria transmission is improbable. We can reduce aK by reducing any one or combination of the factors a, b, s, i and p.

The number of people, p, can in certain cases be reduced by actually moving the residents of one area to another. To materially change p as a method of malaria control is very unusual and expensive, and for the purposes of our discussion we will consider p constant, assuming that migration equals immigration.

The value of i, the proportion of infected people with gametocytes in their peripheral blood, will also be considered constant. The most probable value of this constant might be determined from blood slides taken from various sections of the population at intervals.

The value of b, the proportion of mosquitoes which bite humans, depends on a number of climatic and environmental conditions that may be subjected to alteration. The absolute value of b would be difficult to determine, but the most probable value could be obtained from precipitin tests made on samples of mosquito populations under various climatic and environmental conditions. In the determination and use of b, we have assumed that the mosquito is not conditioned by previous blood meals, although there is no available information on this point.

The biting rate of certain species of anophelines can be influenced by the number and proximity of cattle and other animals.

Screening, and to a degree insecticidal and residual spray, will also change the value of *b*.

Insecticidal and residual sprays can also change the value of *s*, the sporozoite rate. How long the mosquito will live under the climatic and environmental conditions existing in the area under study will determine the value of *s*, the proportion of infected mosquitoes with sporozoites in their salivary glands. Dissection of mosquito glands to obtain a probable value of this factor requires the dissection of a large number of mosquitoes, depending on the value of *im* (proportion of infectious persons). When *im* is very low, the method of determining *s* becomes very laborious. It would be more convenient to estimate *s* by determining the age distribution of a representative sample of the mosquito population, since we know in general the length of time for the development of the parasite to the sporozoite stage in the mosquito. Studies to determine the age of a mosquito by means of some easily distinguished characteristic would be most fruitful in the epidemiology of malaria.

Larviciding and drainage change one factor only, *a*, the number of mosquitoes per person. Moreover, laviciding and drainage often are in conflict with such interests as recreation, wildlife, and impoundments for irrigation, flood control and hydro-electric power, all of which are a part of our national well being, and as such must receive consideration and their due deference from malaria workers. Those factors alone would deter us from choosing larviciding or drainage as an ideal control measure; however, when the high cost, especially in rural areas is added to the above factors, there is left no choice but to place larviciding and drainage in the class of expedient measures to be used at the discretion of the experienced malariologist. The Surgeon General's conference (1940) in this instance said: "It is of great importance to devise a method of attack exclusively effective against mosquitoes but which will not be deleterious to other forms of wildlife of economic value."

Screening will reduce *b*, the biting rate. However, screening gives a sense of security that sometimes is not warranted. Screening, as the word is ordinarily used, implies that the house is mosquito tight — that the doors and windows are never kept open, that the screen wire is kept in perfect repair, and that no path of ingress or egress is available to the mosquito. We know that screen wire is easily damaged and deteriorates. Screening needs care and intelligent attention, and, of course, screening is relatively expensive. For application, as a general control measure in rural areas in our Southern States and in the Tropics, the initial cost and upkeep plus

its ineffectiveness would render screening useful and practical only in certain peculiar situations to supplement a general method of control.

Bed nets, cattle and repellents all have their place and can be used to a limited extent but would not be generally applicable.

LePrince (1918) (1926) in Panama used a fly swatter and catching tube to reduce the number of resting female mosquitoes in barracks, and thereby obtained a material reduction in the incidence of malaria. By the eradication of the engorged and, possibly, infected female mosquito, LePrince intuitively got to the core of the problem of malaria control. By destroying the infected female, LePrince was reducing *s* (the ratio of the number of infectious to the number of infected mosquitoes) to a very low value. It isn't extensive larval breeding in large or numerous bodies of water that causes malaria; it isn't an enormous adult mosquito population, although these are factors and increase the probability of malaria transmission — the agent that transmits malaria is the infectious female mosquito. If every infected female could be destroyed before it became infective and bit a human, extensive breeding and large adult mosquito populations would be of no concern of the malariologist. If the factor *s*, the sporozoite rate, can be reduced to a very low value approaching zero, then aK ($K = b^2sip$) approaches zero and malaria transmission is impossible.

DeMeillon (1936) and Park Ross (1938) in South Africa; Covell, Mulligan and Afridi (1938) and Russell and Knipe (1943) in India; and Soper and Wilson (1943) in South America have used periodic insecticidal sprays to kill resting adult anophelines, and have successfully controlled malaria transmission. Field experience confirms the fact that a reduction in *s* and *b* will effectively control malaria.

The use of a residual toxic spray on the interior walls and furnishings of places of habitation will serve to continuously, instead of periodically as with insecticidal spray, reduce both *b*, the biting rate, and *s*, the sporozoite rate. Knowles and Smith (1945) first demonstrated the effectiveness, ease of application and inexpensiveness of this method, and the Office of Malaria Control in War Areas, U. S. Public Health Service, has used this method successfully in their extended malaria program and sprayed some 300,000 houses in 1945, and plan to spray many more in 1946.

The generally accepted method of malaria control has been the reduction of the mosquito population by larviciding and drainage, a reduction of the single factor *a*, the number of mosquitoes per

person. Screening, that is a mosquito-tight house, if effective would be more efficient that larviciding and drainage, because it reduces *b*, the biting rate, and enters into reduction of malaria transmission as b^2. Insecticidal sprays reduce to a limited extent both *b* and *s*. Residual sprays continuously reduce *s* and *b* and theoretically are more efficent than the reduction of *a* only, or the reduction of *b* only. However, residual sprays, besides being theoretically the most efficient method of malaria control, are relatively inexpensive, quickly and easily put into operations, and, most of all, effective.

Surgeon General Parran (1945) recently wrote: "The job of eradicating malaria — and hence of preventing its reintroduction by returning veterans — no longer can be thought of as the vast and costly undertaking we feared. The use of DDT insures the control of malaria and other insect-borne diseases by means of speedier and relatively inexpensive operations."

Defining the factors involved in malaria transmission and denoting them by symbols eliminates cumbersome phrases from our sequence of thought, and allows us to see clearly and definitely the relative importance of each factor one to another and to their end product, malaria transmission. This discussion has not been extensive or particularly thorough — rather it is an exposition only of the subject and endeavors to show how residual sprays fit into the scheme of things. It is our definition of malaria control; we believe it embodies a new viewpoint for the consideration of malaria workers, which will explain some of our former perplexities, tie together our present knowledge and form a logical compact matrix for the discoveries that shall surely come soon under the impetus of the new war-borne appreciation of scientific research.

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EDUCATIONAL ACTIVITIES AS RELATED TO THE EXTENDED MALARIA CONTROL PROGRAM: A PROGRESS REPORT

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A paper outlining the plans for educational activities as related to the Extended Malaria Control program was presented before the National Malaria Society at its 1944 annual meeting[2]. This paper is a report of further accomplishments since that time.

On January 1, 1945, a budget was approved for the extension of malaria control activities into endemic malarious areas. The principal objective of this program is protection of the civilian population from returning malaria carriers. In addition to drainage and larvicidal operations around populated centers, plans for the first year of operations proposed the application of DDT as a residual spray to more than 300,000 homes in rural areas. Working through State and local health departments, this program is under the general direction of the Office of Malaria Control in War Areas.

This is the first time in the history of malaria control work that DDT has been used as a residual spray over such an extensive civil-populated area. The program involved entering more than 300,000 homes — homes prepared by the occupants for the residual spraying.

The inauguration of a program which required the participation of such large numbers of operational personnel and householders in an entirely new procedure, necessitated a great increase in training and educational activities throughout the malarious areas.

Personnel Training

The first task was to train supervisory and laboring personnel in the mixing and applying of DDT as a residual spray. Only a few individuals on the entire program were acquainted with this type of operation. This problem involved the training of personnel throughout areas in 13 States, at a time when severe travel restrictions were being imposed.

It was decided that the most practical approach was to develop a decentralized training program. Arrangements were made to bring key personnel from State and District offices to the Carter

[1] L. B. Hall, F. M. Hemphill, R. L. Usinger, H. C. Knutson, J .G. Terrill, Jr.

[2] Boyd, Wm. S.: Educational Activities as Related to Returning Malaria Carrier Problem. J. Nat'l Malaria Soc. IV: 147-150.

Memorial Laboratory at Savannah for a short period of intensive training, under the sponsorship of the Training and Education Division of the Atlanta office. Training activities were shared by all the operational and investigational staff who were acquainted with the new procedure, and assistance was rendered by the Central Office in Washington in developing certain educational materials which were used on the program.

With the staff of the Carter Memorial Laboratory, where the procedures for mixing and applying DDT were worked out, a complete breakdown was made of the jobs and equipment necessary in carrying out residual spray operations. With these details completed, there remained the problem of preparations for the training periods to be held for key District and State personnel.

Sound film strips were produced on the following subjects: "Mixing of DDT Emulsions", "Hand Spraying of DDT", "Power Spraying of DDT", and "Safe Practices in the Use of DDT". These film strips presented detailed steps in mixing and applying DDT as a residual spray by hand and power equipment. They were designed for the crew members who would perform these operations. In addition, a film strip entitled "Spray Time" was prepared jointly by the Atlanta office and the Central Office in Washington for use with community groups. The objective of this film strip was to explain malaria transmission and the various modes of attacking the problem, with particular emphasis on the use of DDT as a residual spray, and to instruct the householder in the manner in which their homes should be prepared for residual spraying. A "Handbook on DDT Residual Spray Operations", which covered and amplified the key points shown in the film strips, was prepared and distributed to all workers on the Extended Malaria Control program. In response to requests, the film strips and handbook have received wide distribution in areas beyond those included in the Extended Malaria Control program.

Three training courses were held at the Carter Memorial Laboratory in Savannah during January and February of 1945, with a total attendance of 75. The training was intensive, consisting of lectures, film strips, discussions and quiz sessions. Each procedure was carefully demonstrated and every member of the class was given a period of supervised field practice.

Those receiving training at the Savannah Laboratory returned to the States and held classes for all supervisory and laboring personnel, following much the same procedure that had been used in Savannah. Copies of the film strips and manuals were supplied to

the States for use in personnel training. In some instances, members of the Headquarters Staff with practical experience in residual spraying assisted the States in holding their decentralized training programs. District personnel who had received training in Savannah also worked closely with the States in personnel training.

The decentralized training program, although not ideal, made it possible for residual spraying operations to be started in a rather uniform manner over areas in 13 States. Refresher courses will be held during the winter season. These sessions will make possible an exchange of ideas gained from the previous season of operations which will enable field and headquarters personnel to improve on both training and operational procedures.

To acquaint all interested personnel with the history, policy and operations of the Extended Malaria Control program, a bulletin was issued on the subject and distributed throughout the service and to all State and local public health departments in the malarious areas of the United States.

Orientation and training courses in the Headquarters Office in Atlanta have continued throughout the year. The subject matter of these courses covered the entire field of malaria control practices. In addition to the regular trainees, both officers and civilians, representatives of a number of foreign countries as well as members of the staff destined for foreign duty received training in malaria prevention through these courses.

A special course was held for medical consultants from areas beyond the limits of the extended program. In this course emphasis was placed on epidemiology, diagnosis and entomological aspects of malaria. Mobile unit supervisors also received training in residual spray operations and a short course was held for health educators.

Public Education

An effort has been made to inject malaria emphasis into as many educational channels as practical. However, primary emphasis in lay education has been confined to those areas where the malaria hazard is greatest. The Headquarters Office in Atlanta, as well as the Central Office in Washington, has encouraged the publication of accurate articles on malaria in widely circulated newspapers and magazines. Since malaria has played such an important part in World War II there has been an increase in national interest in the disease. The advent of DDT has also stimulated wide interest in the use of this substance as an insecticide. Because of these two factors a number of articles on malaria have appeared in national

magazines and several network radio programs have been devoted to this subject. These releases have served to sensitize the public and have thus aided in the more specific educational effort.

Public education activities at the community level have been the responsibility of State and local health departments. The MCWA Headquarters Office has provided administrative services, educational material and equipment when requested. One member of the staff has served as a public education consultant to state health departments. The emphasis placed on educational phases of the malaria control program has varied from state to state. In some states malaria education was introduced into the general health education program, while in others public education work was carried on by operational personnel. In several states "malaria control assistants" were assigned to the area supervisor and had the responsibility of conducting the public education program in the community.

The public education program has been carried on chiefly through individual and group discussions. Extensive use has been made of film strips, motion pictures, printed materials and newspaper releases. The radio has not been used to any great extent for disseminating information in public education activities because of the limited geographic areas included in the extended progra...

In the educational effort an attempt has been made to achieve community enlightenment and participation in malaria control practices. The householder has been asked to assist in operations by preparing his home for the residual spraying. Preparation of the home prior to the arrival of the spraying crew has enabled operational personnel to spray more than twice as many homes as would have otherwise been possible.

To increase the effectiveness of the residual spraying, householders were also encourgaed to repair broken screens and to sleep and rest within the dwellings that had been sprayed.

It was estimated from state reports that more than 75,000 persons a month have been given basic information on malaria and its prevention through local group work since March 1945. An estimated 500,000 per month have received information through all channels.

The effectiveness of DDT in killing a variety of household insect pests has made it very popular and there has been a great demand for its use in areas not covered by the Extended Malaria Control program. In some instances much time has been spent in public relations in explaining why the residual spray was being used in a confined area and that it was being used to control malaria-

carrying mosquitoes rather than relieve the householder of other insect pests.

Professional Relations

Workshops were held at a number of state teacher colleges in several states. A large number of teachers in malarious areas have received detailed instructions on malaria and malaria control practices and have worked out units on this subject which will be included in the school curriculum. Notable examples of the states where the workshop technique was used are: Arkansas, Mississippi, and Kentucky. The Tennessee Valley Authority also participated in the workshop held in Kentucky.

Other professional relations activities have included consultation to various agencies interested in malaria control work. Materials have been provided to a number of biologists and engineers in various universities which will be useful to them in teaching malaria preventive practices.

As a part of the Tropical Disease Education program, an intensive course has been given to technicians from 20 state health departments in the microscopical diagnosis of human malaria. An extension service is being offered whereby malaria smears are sent to the laboratories to assist in refresher training of technicians.

Material Production and Distribution

A variety of materials have been produced for use in connection with training and educational work. These materials have included film strips, motion pictures, lantern slides, handbills, cartoon strips, manuals and informational booklets. As a joint undertaking between the Tennessee Valley Authority and the U. S. Public Health Service, four motion pictures have been prepared on the subject of malaria control in impounded waters. These will be released in the near future and should be of great use in connection with the expansion of the national program of reservoir development.

A small booklet, "So You've Had Malaria", designed for discharged veterans, has been prepared by the Atlanta office. This booklet gives a brief message to the veteran and indicates what he can do to assist in preventing malaria in the community to which he returns.

Projection equipment has been provided to the states for use in connection with public education activities. Thirty sound motion picture projectors and 148 film strip projectors with sound attachment, are now on loan to state health departments from the Atlanta office. Eight generators have been provided for use in communities where other sources of electricity are not available.

The following tabulation indicates the numbers and types of materials that have been distributed from the Atlanta office during the past year:

I. *Film Strips and Records*
- A. Number of subjects 20
- B. Total number distributed to state health departments and educational institutions 1470

II. *Motion Pictures*
- A. Number of Subjects 18
- B. Total number distributed to states.......... 80

III. *Printed Publications*
- A. For Professional Groups:
  1. Number of units, including charts, handbooks, books and pamphlets 33
  2. Total number distributed 32,000
- B. For Lay Groups:
  1. Number of units, including booklets, cartoon strips, posters, handbills, etc. 18
  2. Total number distributed 1,055,000

Conclusion

Education efforts are extremely difficult to evaluate. It is true that a certain degree of accomplishment is indicated by the number of individual and group contacts that have been made; the number of people who have seen film strips and motion pictures on the subject; the number of volumn inches on malaria that have appeared in newspapers, and the number of handbills and other materials that have been distributed. This is not the measure that we have sought in attempting to evaluate the effectiveness of the educational program.

During our present period of low malaria incidence, it is not possible to evaluate the effectiveness of our educational efforts any more than it is possible to determine the efficacy of DDT as a residual spray. The ultimate criterion for evaluating any malaria preventive technique is whether or not malaria is reduced or prevented by the procedure. With malaria at such a low ebb, we must rely on other criteria to determine the effectiveness of our efforts. The fact that approximately 400,000 homes have been entered and sprayed with DDT throughout the endemic malarious areas during this season indicates substantial public interest and acceptance. It is estimated that less than 2% of the homes in the endemic malarious areas have not been sprayed because of lack of cooperation from house holders. It is recognized that the popularity of DDT was an important factor in its acceptance after the program was started. In certain communities where no public education was done, spraying

crews were greatly retarded in their activities because householders had not prepared their homes for spraying. After educational activities were started, operations proceeded more rapidly.

The evidence thus far indicates that personnel training has enabled the program to get underway much more rapidly and with greater uniformity and has increased the efficiency of operations. Evidence also indicates that the service which has been rendered during the past year has contributed to the enlightenment of communities where malaria has been and is likely to be a health problem.

Educational work related to malaria and its prevention is by no means complete. The Public Health Service will continue to offer assistance in personnel training and professional and public education to health departments, institutions and other agencies concerned with the malaria problem.

RELATIONSHIP OF MEMBERS TO ADVERTISING:

The membership is urged to participate in securing advertising for the Journal and to patronize the advertisers. The members realize the benefits of advertising in the Journal as all of the revenue secured therefrom is used to increase the size of the Journal. Consequently, the more advertising secured, the more papers which can be printed for authors, and the more information available to the readers.

Any suggestions as to advertising, particularly in respect to new accounts, will be gratefully received by the Secretary.

BLOOD OXYGEN IN DUCKS WITH MALARIA*

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(Received for publication 14 November 1945)

It has been suggested from pathological studies that anoxia is an important factor in the mechanism of death in acute malaria (Rigdon 1942a, 1942b, 1944). This anoxia results from the rapid destruction of red cells by the plasmodiae. Hewitt (1942) has said that a decrease in the number of red cells, accompanied by a diminution in hemoglobin, is a characteristic manifestation of all types of acute malarial infections.

It has been shown that ducks infected with *P. lophurae* when placed in a decompression chamber succumb before the normal birds (Rostorfer, 1945). Furthermore, the survival time at simulated altitude of these ducks with malaria is proportional to the severity of the malarial infection. Ducks show, therefore, the effect of anemic anoxia before they reach the terminal stages of the disease.

Wong (1945) recently measured the amount of oxygen in the blood of neurosyphilitic patients treated with malaria and found a variation in the degree of blood oxygen saturation. He suggests the presence of some factor which inhibited full oxygenation of the hemoglobin during the infection.

The experimental observations cited above would suggest that a disturbance occurs in the oxygen saturation of the blood in ducks with *P. lophurae*. In this paper the experimental results of such a study are given.

Methods and Materials

Plasmodium lophurae was used in this study to infect young white Pekin ducks from 15 to 20 days old. Parasites used for the inoculum were obtained from highly parasitized donor birds. The blood was mixed with an equal volume of a 2.0 per cent sodium citrate solution in physologic saline. The parasitemia was followed by counting the number of parasitized cells per 500 red cells. Smears were stained with a combination of Giemsa and Wright stains. Standard methods were used in counting the red blood cells. Young

*Read at a meeting of the National Malaria Society in Conjunction with the American Society of Tropical Medicine, November 14, 1945, Cincinnati, Ohio. This work was supported by a grant from the John and Mary R. Markle Foundation. The anticogulant used in these experiments was Liquaeomin supplied by Roche-Oranon Inc., Nutley, New Jersey. Research paper 576, Journal Series, University of Arkansas.

erythrocytes were differentiated from adult red cells by the dark staining of the cytoplasma and the round nucleus.

Sampling: Blood samples for gas analysis were taken from heart puncture from 4 to 5 ducks and pooled. Coagulation was prevented by using 1 ml. of a one per cent solution of the sodium salt of heparin for each 9 ml. of blood. The use of this relatively large amount of heparin has been discussed by Rostofer and Rigdon (1946)

Equilibrations: The blood was equilibrated as described in another publication (Rostorfer and Rigdon, 1946). Samples of one and one-half ml. of heparinated blood was equilibrated in Bar-

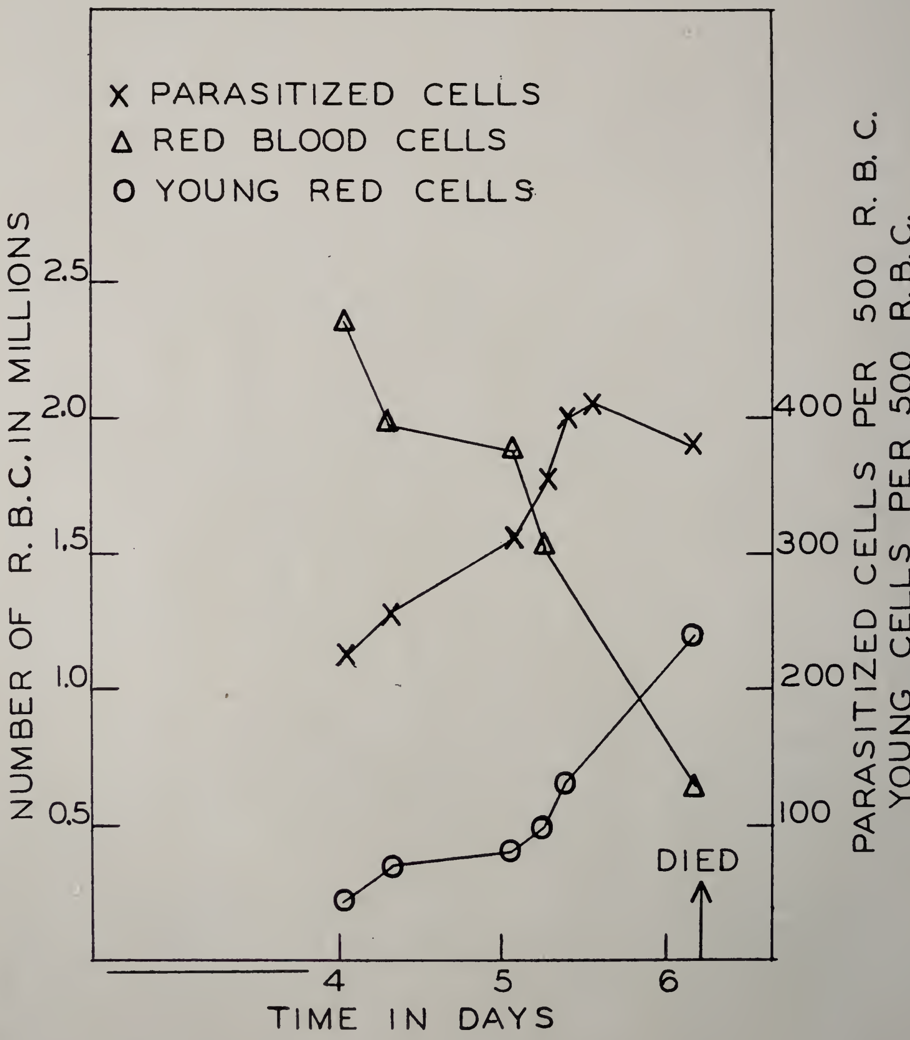

Figure 1. Typical course of *P. lophurae* infection in a young duck.

croft tonometers for 10 minutes. The equilibration was repeated three times and the tonometers were flushed out with fresh equilibrating gas at the beginning of each equilibration period. The oxygen and carbon dioxide content of these samples were found to agree with duplicate samples equilibrated for longer periods. All samples were equilibrated at 38 degrees C.

Oxygen Capacities: Oxygen capacities were determined by manometric analysis of blood equilibrated with air.

Oxygen Dissociation Curves: Curves were obtained by equilibrating blood with gas mixtures containing 3.49 per cent, 7.44 per cent and 11.89 per cent oxygen. The percentage of carbon dioxide present in each mixture was 3.40 per cent. The curves plotted by the use of the formula $y - \frac{1 - kX^n.}{100\ kX^n.}$ The Constant K and the exponent "n" were calculated from the data obtained by equiliberating samples at 52 and 83 mm. Hg. of oxygen tension.

Hemoglobin Determinations: Hemoglobin was determined in the heparinized sample of blood by the method of Schultze and Elvehjen (1934).

Color Index: The color index was calculated by dividing the number of grams of hemoglobin per 100 ml. of blood, which had in turn been calculated from the oxygen capacity, by the cell count expressed in millions of cell per cu. mm.

Experimental

The characteristic course of a fatal *P. lophurae* infection in ducks is shown in figure 1. There occurs a rapid increase in the number of parasites and a corresponding decrease in the number of red blood cells. The number of young erythrocytes in the peripheral blood rapidly increases during the development of the anemia. A decrease in the number of parasitized cells from the highest point reached at the peak of the infection usually occurs preceding death. The peripheral blood may show as few as 300,000 red blood cells at the time of death. Ducks infected with a decreasing number of parasites show a corresponding decrease in the number of parasites and a less severe anemia. A variation in the course of infection likewise occurs in ducks of different ages. The birds used in this study show the type of response to *P. lophurae* as shown in figure 1.

A comparison of the oxygen carrying capacity, that is, the volumes per cent of oxygen taken up by the blood at any given oxygen tension, is graphically expressed in figure 2 for normal blood and blood from malarial infected ducks obtained at different stages

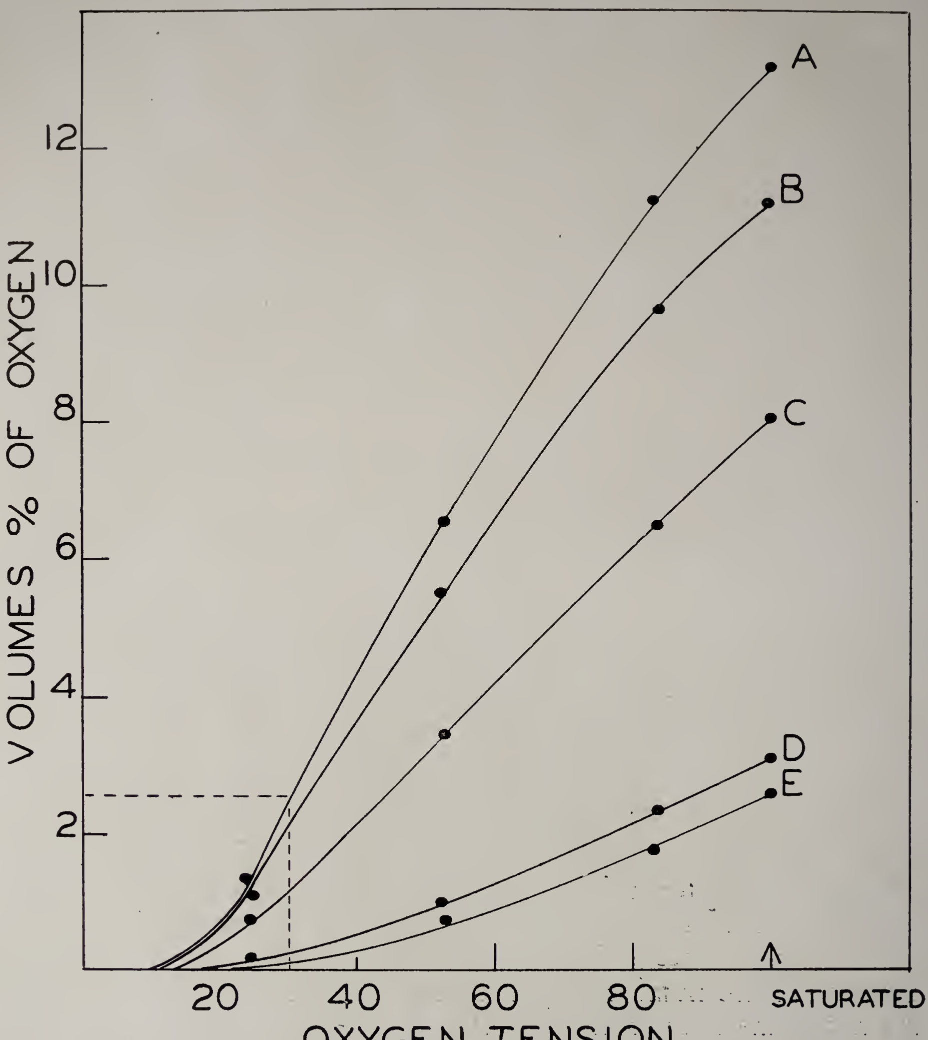

Figure 2.—A comparison of the volumes per cent of oxygen carried by the blood of ducks during different stages of *P. lophurae* infection:

A. Blood from normal duck

B. R.B.C. count 2.03 M; 190 parasitized cells per 500 R.B.C. on 4th day of infection.

C. R.B.C. count 1.45 M; 340 parasitized cells per 500 R.B.C. on 5th day of infection.

D. R.B.C. count .80 M; 325 parasitized cells per 500 R.B.C. on 6th day of infection.

E. R.B.C count .54 M; 260 parasitized cells per 500 R.B.C. in moribund birds.

The oxygen capacity at saturation is plotted on the extreme right.

during the infection. Curve A in Figure 2 represents the oxygen carrying capacity for normal duck blood of similar age. Curves B, C, and D were determined from blood taken from malarial infected birds on the 4th, 5th and 6th day after inoculation. Curve E was obtained from blood taken from moribund birds on the 6th day following inoculation. The dotted line represents the amount of oxygen that normal blood would take up if it were equilibrated at an oxygen tension equivalent to the partial pressure of oxygen prevailing at an altitude of 38,000 feet. Experiments with a decompression chamber have demonstrated that a simulated altitude of 38,000 feet is approximately the lethal altitude for ducks from 18 to 21 days old (Rostorfer and Rigdon, 1945).

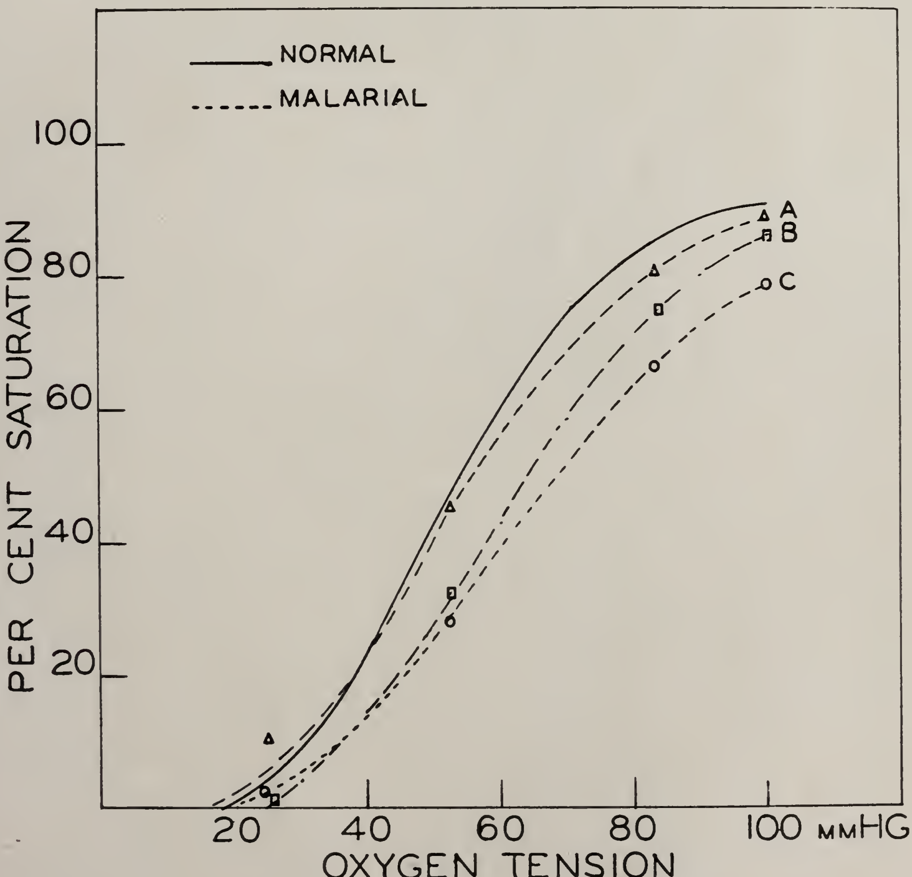

Figure 3.—A comparison of oxygen dissociation curves. Curves A, B and C represent blood obtained on the 4th, 5th and 6th day after inoculation. Curves were plotted according to Hill's formula.

Figure 3 represents a group of curves including a normal curve and curves A, B, and C obtained from blood of malaria infected birds on the 4th, 5th and 6th day after inoculation. These curves demonstrate a lowering and a definite shift to the right. This shift is a reflection of the increasing acidosis which is evident from the change of the CO_2 combining power at 31 mm. Hg CO_2 tension, which is 33 volumes per cent CO_2 for normal duck blood. In the terminal stages of the malaria infection the CO_2 combining power at 31mm. Hg. is between 18 and 19 volumes per cent. During the first four days of the infection the shift is meager, yet during the last few hours of life the shift to the right is pronounced.

Some of the ducks survive the malarial infection and have a short period of rapid recovery. Figure 4 shows the dissocoiation

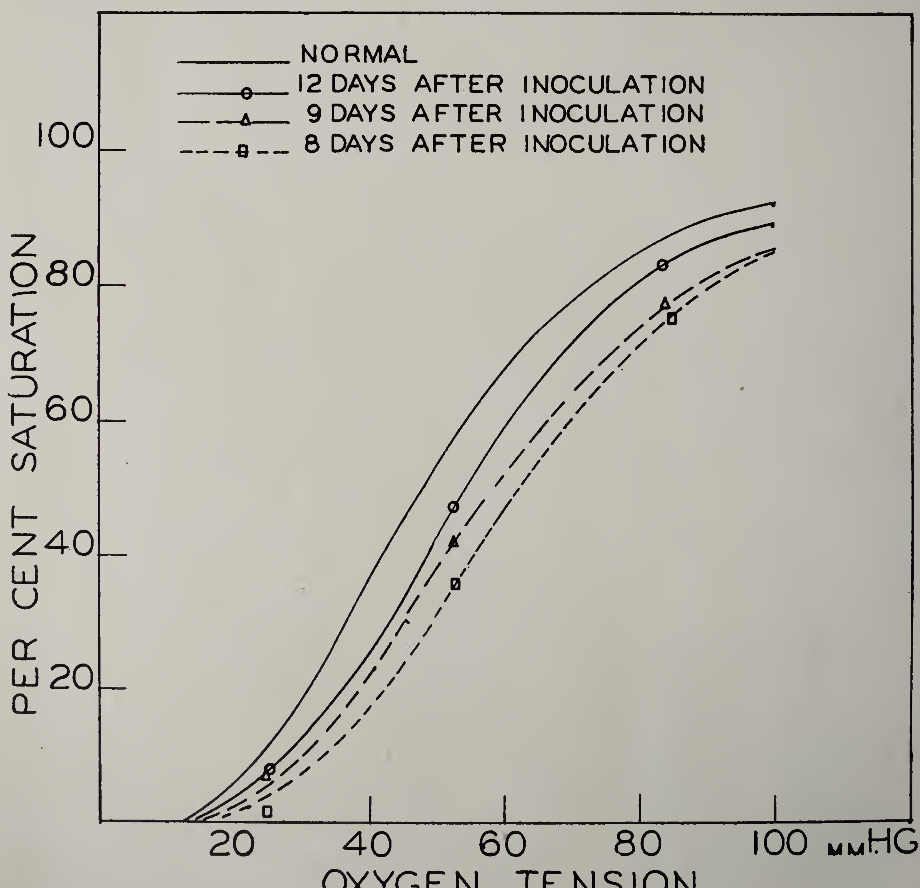

Figure 4.—A comparison of oxygen dissociation curves obtained during the recovery phase of malarial infections.

curves obtained from birds on the 8th, 9th and 12th day after inoculation. No parasites were demonstrated in 500 cells in this blood and 50 to 60 percent of the cells were young erythrocytes. Acidosis is still evident on the eighth and ninth days after inoculation.

A linear relationship exists between the hemoglobin of duck blood calculated from the oxygen capacity and the hemoglobin determined colorimetrically by the Schultze and Elvehjem method (Rostorfer and Rigon, 1946). The effect of malaria on this relationship is graphically represented in Figure 5. The numbers

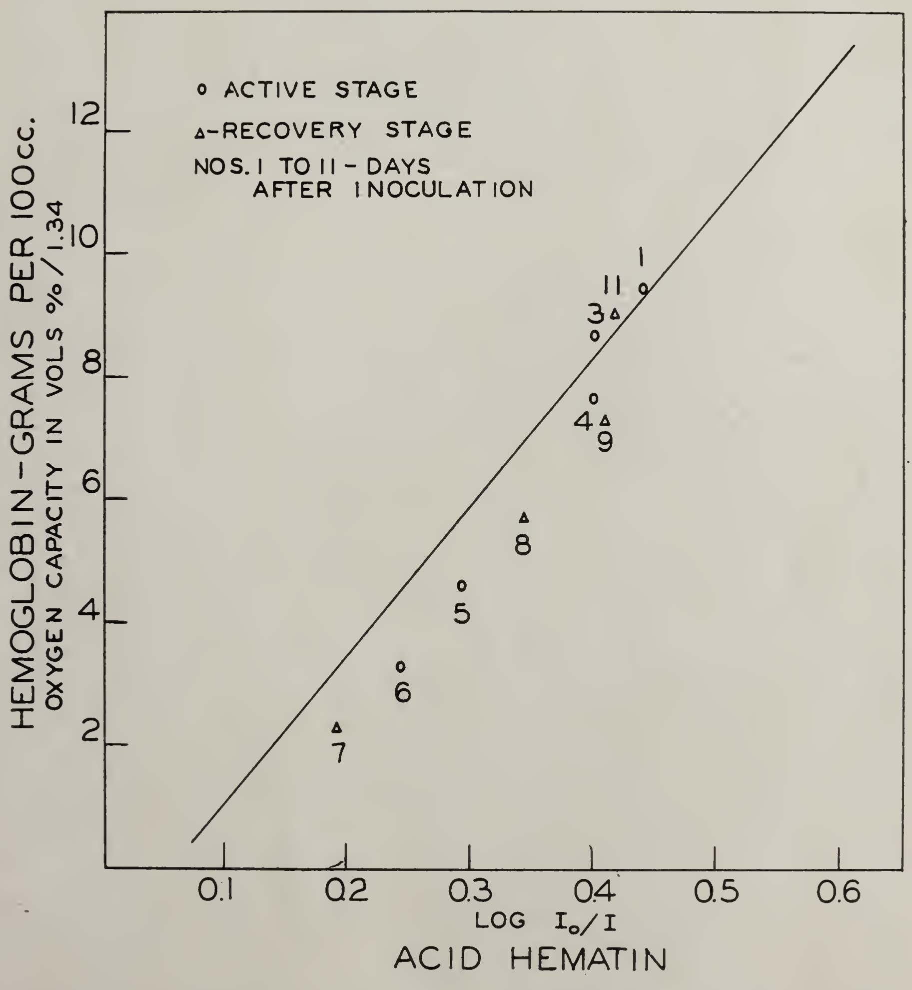

Figure 5.—A comparison of the amount of hemoglobin calculated from the oxygen capacity and the amount of hemoglobin determined colorimetrically. The diagonal line is the linear relationship for the hemoglobin in the blood of normal ducks.

above or below the experimental points indicate the days after inoculation. The diagonal line is the linear expression for the blood of normal birds of similar age. The hemoglobin on the 1st, 3rd, and 11th day following inoculation has the normal linear relationship. The hemoglobin removed from the infected birds on the 4th, 5th, 6th, 7th, 8th and 9th day shows a linear relationship to the right of the normal. The parasitemia was over 300 parasitized cells in 500 red blood cells on the sixth day after inoculation. On the 7th day after inoculation few parasites were demonstrated per 500 red cells and the reticulocytes composed 50 to 60 per cent of the total number of cells. The color index of the blood at this time was 2.2×10^{11} in comparison to 3.17×10^{11} for the normal blood. The points fell higher on the same parallel line as the anemia was overcome. The normal linear relationship was not re-established, however, until the 10th and 11th day after inoculation. When this relationship was re-established, the color index was 3.5×10^{11}.

Discussion

The experimental results of this study show conclusively that there is a decrease in the amount of oxygen carried by the blood during the course of *P. lophurae* infection in ducks, and furthermore, the amount of this decrease is proportional to the severity of the infection. The blood of moribund birds has only 20 per cent of the normal oxygen capacity as compared to the normal birds of similar age. Accompanying this fall in oxygen capacity during the course of the disease, there is an acidosis which decreases further the oxygen carrying capacity of the blood. If the bird survives the infection there is a gradual increase in the number of red cells, the amount of hemoglobin and the oxygen capacity as is shown in Figures 4 and 5.

The oxygen capacity of the blood from moribund birds is approximately equal to the amount of oxygen the blood of normal birds would hold if equilibrated at an oxygen tension equivalent to that prevailing at an altitude of 38,000 feet. If one considers the general shape of the dissociation curve and the observation that duck blood has apparently little affinity for oxygen at extremely low O_2 tension, the conclusion is obvious that survival, at extremely high altitudes and in the case of extremely severe anemia, is the result of energy liberation from some system not requiring complete oxidation; possible glycolysis because there is a very rapid disappearance of blood glucose during the terminal phases of the infection (Marvin and Rigdon, 1945).

The relationship between the hemoglobin determined by calculation from the oxygen capacity and hemoglobin determined colorimetrically is decidedly different from the normal. The cause of this difference is being investigated in the laboratory. It is evident, however, that the hemoglobin, if the methods of Schultze and Elvehjem measures only hemoglobin in malarial blood, is not completely oxygenated. However, if malarial pigment is included as hemoglobin and recorded as such in the analysis it would possibly explain the deviation of malarial blood from the normal linear expression between the amount of hemoglobin determined colorimetrically and the hemoglobin calculated from the oxygen capacity. It is apparent that the amount of hemoglobin as determined colorimetrically is larger than the amount of hemoglobin calculated from the O_2 capacity in malaria blood. However, the normal relationship is not immediately re-established after the parasitized cells have disappeared. The young red cells which are so abundant from the seventh to the ninth day are not efficient oxygen carriers. The amount of "functional" hemoglobin is considerably less in these young cells. It is only after the disappearance of the young cells that the hemoglobin has a normal oxygen carrying capacity.

The decrease in the amount of oxygen in the blood during malarial infection results, primarily, from the rapid destruction of the red cells by the parasites. The accompanying acidosis also, may be a contributing factor in the further reduction of the oxygen carrying capacity.

In considering the role of anoxia in acute malarial infections in man, it should be remembered that this infection is usually accompanied by an elevated temperature and that the increment of oxygen utilization follows the normal Q_{10} for biological reactions. The stain on the oxygen transportation system may be increased by the elevated temperature and this contributes indirectly to the anoxia produced by the acute anemia.

Summary

1. The oxygen capacity of the blood is greatly reduced during *P. lophurae* infection in the duck. At the time of death, the blood may have only 20 per cent of the normal oxygen capacity.
2. During the course of the malarial infection in the duck a severe acidosis develops which also reduces the efficiency of the blood as an oxygen transporting medium.
3. The young cells are not efficient oxygen carriers in comparison to normal adult red cells.

4. Death of birds infected with *P. lophurae* is caused by failure of the blood to carry a sufficient amount of oxygen to support life.

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MALARIA CONTROL ACTIVITIES DURING THE CONSTRUCTION OF AN ADVANCED TROPICAL NAVAL BASE[1]

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(Received for publication 31 May 1946)

Soon after the beginning of construction of Naval Bases in the Caribbean Region, it became apparent that the effects of malaria on continental workers transported into the region presented an obstacle of primary importance. With the introduction of susceptible continental civilian workers into areas of high malaria endemicity, without adequate provisions being made for malaria control, a circumstance highly favorable to the development of outbreaks of the disease developed. Such an outbreak did occur, with the prevalence of the disease among the key civilians reaching such proportions as to threaten a suspension of construction. Important men in construction began to return to the United States, either having had several attacks of malaria, or after having witnessed the effects of the disease in others. Information concerning these conditions reached prospective employees in the United States, and replacements for departing personnel become difficult to obtain.

After an outbreak of malaria, the Navy assumed the task of affording protection to workers engaged in construction activities. A specialist was assigned to this base to organize and direct malaria control. A civilian physician, employed by the contractors, was immediately engaged. A dormitory was converted into a temporary hospital, and thirty-six malaria patients were hospitalized and treated. Additional cases were being treated without hospitalization. Examinations of water surfaces showed *Anopheles* larvae to be present in considerable numbers in all bodies of water, and adult *Anopheles albimanus* Wiedeman were found in the tents on early morning inspections. A labor crew was hurriedly organized for mosquito control. Immediately, clearing of vegetation, canalizing streams, application of diesel oil No. 2 to all water surfaces, and spraying tents and quarters with pyrethrum extract were inaugurated as emergency measures in all situations in the vicinity of camps. Relationship with the construction authorities proved to be of primary importance to the success of the program.

[1] The expressions contained in this paper are the private ones of the author and are not intended to represnt official viws of the Navy Department.

[2] Commander, USNR.

Description of Area

The base with which this report deals is located in the Caribbean Region on an important island formation and is divided into two areas. One of these areas is on the main island, and in this report will be referred to as area "A". The other is on a small islet several miles distant from the main island, and in this report will be referred to as area "B".

Area "A" is on the coastal margin of the main island and is comprised of approximately 13,000 acres. Elevations vary from zero to approximately 300 feet above mean sea level. Having been formerely devoted to growing sugar cane, the area was traversed by innumerable irrigation ditches and furrows. Three sluggish streams traversing the area and bringing water from the inland hills provided a constant source of water for the production of *An. albimanus* Wiedeman in the ditches and furrows. Extensive mangrove swamps mordered the coastal margin of the area. The average annual rainfall at an observtion point eight miles away is sixty-eight inches. Peaks of rainfall usually occur in June and November. Temperatures in the area present little variation from season to season. During the period covered in this report, the mean maximum summer temperature was 85.3 degrees fahrenheit, and the mean minimum was 75.3 degrees. During the winter months, these temperatures were 83.8 and 73.5 degrees, respectively. Seventy-two native huts were occupied by squatters within the area. Area "B" is on an islet nine miles away from area "A", and geologically is a prolongation of the main island. Narrow coastal lowlands surrounded a range of hills, the highest of which rises to almost 1,000 feet above mean sea level. Steep hillsides and sixteen rapidly flowing streams characterize the area. It is approximately 7000 acres in area.

The chief source of mosquito production was an area embracing three large mangrove swamps, comprising about 700 acres, of which about 400 were covered by fresh water land-locked ponds. The summer and winter temperatures vary only about five degrees Fahrenheit. Early morning temperatures in August are about 76° F., rising to 90° at noon. In January, these temperatures are about 70 and 80 degrees, respectively. The maximum recorded temperature is 90 degrees, and the minimum, 61. Average rainfall over thirty years is 45.72 inches. Variations in rainfall from month to month are considerable, with a peak occurring during the months of September, October or November, and a lesser peak in May or June. When malaria control was undertaken, 281 huts on the reservation were occupied by natives.

Evaluation of Problems

Blood Film Surveys: At the time malaria control was instituted, there were 143 continentals and 157 natives residing in the camp in area "B". Moreover, 14 continentals and 1,300 natives who did not reside in the camp were employed. On December the 4th, 1941, thick blood films were made on 246 employees, exclusive of patients being treated for malaria. Of the employees examined, 48 were continentals. Individuals examined constituted a random sample of the camp population. Examination of these slides was done by the local Public Health Agency, and the results are summarized in Table 1.

Table I.—Malaria Survey of 246 Persons in Area "B", December 4, 1941

Examinations	Continentals	Natives	Total
No. Examined	48	198	246
No. Positive			
P. falciparum	5	33	38
P. vivax	1	25	26
P. f. & P. v	1	3	4
P. v. & P. m.	0	1	1
Total positive	7	62	69
Per cent positive	14.6	31.3	28.0

From Table 1, it is apparent that the infection rate for *Plasmodium falciparum* was high in both continentals and natives as compared with the other species of *Plasmodium*. This survey, considered according to residence of individuals in Table 4, further suggests that the high indices of infection were not a result of living under conditions of camp life. Actually, the rate was lower for natives living in the camp than from those not living in the camp. Fifty-nine non-residents of camp included in this survey were all natives. From the results of this survey and from the clinical manifestation of the disease, it is evident that area "B" was an intense focus of malaria infection.

The first blood survey in area "A" was conducted on February 20, 1942. From this survey, there was nothing to indicate that the prevalence of malaria in area "A" was any cause for alarm. Blood surveys were repeated on samples of the camp population in both areas at approximately six month intervls to serve as a check on the intensity of the disease, as well as to determine the relative prevalence of the different species of parasites.

Mosquito Surveys: As a measure of the effectiveness of control measures employed, collections of mosquitoes were made throughout the period covered in this report. Zones of successive one mile distances were established about the peripheries of the camp areas. Adult mosquitoes were collected by routine observations in tents, buildings, and other situations in which they might be found, and by the operation of animal bait traps using horses for bait. All water

surfaces were inspected routinely in search of larvae. Inspections for adult and for larvae were conducted in accordance with a rigidly fixed schedule.

Table 2.—Malaria Morbidity—Camp Resident Area "A"

Month	Susceptible Camp Population	No. of Cases	Cases per 1000 Population
January 1942	300	3	10.0
February	----	--	----
March	300	1	3.3
April	341	3	8.8
May	407	0	0.0
June	441	3	6.8
July	488	1	2.1
August	572	2	3.5
September	654	1	1.5
October	846	2	2.4
November	916	1	1.1
December	960	2	2.1
January, 1943	1050	2	1.9
February	1650	1	0.6
March	2199	5	2.3
April	2472	1	0.4
May	2256	3	1.3
June	2284	2	0.9
July	2103	2	0.9
August	2936	1	0.3
September	2186	1	0.4

Table 3. Malaria Morbidity — Camp Residents Area "B"

Month	Susceptible Camp Population	No. of Cases	Cases per 1000 Population
September 1941	150	1	6.6
October	250	22	88.0
November	290	47	162.1
December	247	103	343
January 1942	300	71	255
February	363	79	217
March	428	45	106
April	489	22	45
May	549	21	38
June	615	17	27.6
July	677	12	17.8
August	741	15	20.1
September	811	11	13.3
October	844	23	27.2
November	856	18	21.0
December	877	18	20.6
January 1943	971	12	12.4
February	1112	12	10.8
March	1116	7	6.3
April	868	9	10.4
May	789	3	3.8
June	378	5	12.3
July	142	0	0.0
August	85	0	0.0
September	74	1	13.5

Control Measures Employed

Emergency Measures: The measures of control employed in response to the emergency conditions that existed have already been indicated.

Preventive Measures: When control activities had become organized and established, all available means of controlling malaria and mosquitoes were employed. They are conveniently grouped as: (1) measures of defense; and (2) measures of attack.

Segregation: All native houses on the reservation were removed to sites selected for this purpose about eight miles from the camp. The removal of this source of infection from the vicinities of camp probably constitutes one of the most important measures of control undertaken. Though not always feasible, it is a measure strongly recommended under conditions that permit it.

Special dormitories were constructed about one mile from the continental camp in which native workers, to be retained on the reservation, were housed. Natives not residing on the reservation were required to leave before sunset.

Screening: All buildings used for quarters, offices, and mess were screened with eighteen mesh screen so that all doors, windows, and ventilators were covered. All beds were equipped with nets and the occupants strongly urged to use them. Head nets were made available to those exposed to mosquitoes at night in uncontrolled zones. Their use was temporary.

Repellents: Lotions to repel mosquitoes were provided for individuals engaged in night work in uncontrolled zones.

Chemotherapy: Individuals who became ill with malaria were treated by the camp physician. Others who through microscopic blood examinations were found to be parasitized were likewise treated. Blood examination of all prospective employees was established as a condition of employment, and those found to be infected were treated.

Hand Catching: All tents, quarters and other buildings within and underneath, were carefully searched once each week and mosquitoes encountered were captured. Such situations in which mosquitoes were numerous were examined once each day.

Trapping: Animal bait traps at the beginning of their use and subsequently in uncontrolled zones yielded large numbers of mosquitoes. Several thousand in a single collection were not uncommon. The maximum number in a single night's operation was in excess of 5,700 specimens, of which 2,300 were *An. albimanus*. In each of the areas, ten such traps were operated on two successive

nights each week. In selected localities, traps were operated each night during certain periods. The traps were distributed throughout the area in more or less permanent locations so that data regardin trap collections would be comparable from one time period to another.

Fumigants and Sprays: For a number of months, all quarters were thoroughly sprayed early each morning and again after nightfall with pyrethrum extract in kerosene. It was found that this measure could be discontinued after the mosquito population had been reduced to a comparatively negligible level. Theaters, chapels and other places of assembly were sprayed thirty minutes before performances. Picnics and swimming after sunset were strongly discouraged.

Clearing and Conditioning of Water Surfaces: All streams and other surfaces were brushed and cleared periodically in accordance with a fixed schedule. The removal of protective vegetation reduces larval food supply, exposes them to wave action and to fish and insect enemies, admits sunlight and air currents which hasten evaporation, and increases the effectiveness of larvicides. It is considered that this measure was very valuable in the anti-larval campaign.

As a corollary to clearing, stream beds were straightened and pot-holes were filled, confining the stream flow to narrow channels in which the water flowed rapidly. This measure was particularly applicable to the hillside streams in area "B".

Larvicides: All water surfaces found to be producing mosquitoes on weekly inspections were treated with larvicides. The practice was to use diesel oil No. 2 on situations nearest camp, so as to kill larvae of pest mosquitoes as well as anopheline larvae and to use paris green on the outlying or distant situations. Diesel oil No. 2, available on the reservation, approximated the ideal larvicide and was used extensively. Oil was applied from portable sling type pressure sprayers which delivered a finely atomized spray to settle on the water surface. One hundred per cent mortality of anopheline larvae usually resulted within one hour after application. Rate of application was about twenty gallons per acre of water surface. About forty gallons per day per oiler were applied. Oiling was done once each week according to a rigidly fixed schedule.

The paris green used was requested to meet the specifications recommended by the Health and Safety Department of the Tennessee Valley Authority. It was mixed in the proportion of one to ten either with hydrated lime or calcium carbonate. Application

was by hand operated rotary blowers, or by mechanical dusters operated from boat or truck. Rate of application was approximately one pound of paris green per acre.

The use of larvicides occupied a defnite but auxiliary place in the mosquito control program.

Natural Enemies: Fish (*Lebistes reticulatus*), that are predaceous on mosquito larvae, occur abundantly in the fresh-water streams in the area under consideration. If protected, they multiply rapidly. Clearing streams and channels of vegetation and debris removes protection for mosquito larvae and renders them more accessible to fish.

Drainage: In the established malaria control program, after the problem has been evaluated, drainage of area in which mosquitoes were being produced became a primary measure of control. Except for the emergency measures which merely involved removal of water as quickly as possible, drainage of all water surfaces which it was practicable to drain, was done according to engineering practices employed by malaria control engineers. In area "A," approximately seventy-six miles, and in area "B", approximately fifteen miles of semi-permanent ditches were so constructed.

As the variations in rainfall from one season to another were considerable and the run-off from the steep rocky hillsides was high, it was necessary to construct drainage systems that would keep the residual water moving rapidly in normal dry weather and would not be destroyed by erosion under flood conditions.

Maintenance of Ditches: All ditches were inspected and maintained each week. The operation of heavy mechanical construction equipment necessitated frequent repair work to drainage systems during the period of construction of the base.

Concrete or masonry baffles were installed in the ditches to maintain grades and prevent extensive erosion.

"Inverts" of concrete were installed in the main ditches and the slopes planted to Bermuda grass as additional measures of stabilization.

Filling: The most nearly permanent measures of control practiced was that of filling. Certain mangrove swamps that were enormous potential sources of mosquito production were filled by discharging dredged material into them. Extensive hydraulic dredging operations were conducted for construction purposes and an arrangement was made for the spoil to be discharged into the low areas where mosquitoes were being produced. Other areas such as stream beds from which the streams had been diverted were filled by trucks to the extent that they would readily drain.

Salinization: Several fresh water and moderately brackish ponds that produced *An. albimanus* abundantly existed as land-locked ponds behind barrier beaches that were built by wave action. By experimentation, it was determined that water of a salinity greater than fifty per cent of sea water concentration was detrimental to the development of *An. albimanus* larvae, and that seventy-five per cent sea water concentration prevented development entirely. These ponds were then connected with the sea by channels and the slainity increased sufficiently to stop production entirely. Hundreds of acres of water surfaces were rendered non-productive of anophelines by this measure, thereby, obviating the necessity for airplane dusting.

Evaluation of Control

In an attempt to measure the effectiveness of control measures from time to time and to determine the prevalence of malaria and its vectors, accurate records were kept of all phases of the work. They include morbidity records pertaining to continental and native populations, residents and non-resident of the camp; records of blood survey infection rates; records of adult anophelines collected in natural resting places and in animal bait traps; records of precipitation; and records of anopheline larvae collected. The data from these records are summarized in the accompanying tables and charts.

Morbidity: According to Earle (1939), the incidence of illness due to infection with *Plasmodium vivax* in the area with which this paper is concerned begins to increase in May and reaches a peak in August, after which there is a slight reduction followed by a second (and frequently greater) peak in October or November. *P. falciparum* increases in incidence throughout the summer and autumn, and reaches a peak in December. The perception of two annual peaks of malaria is further emphasized by the mortality rate, which shows one peak in mid-summer and another in December. Chart I, Figure 1, indicates the continuous net decline in malaria morbidity of camp residents in area "A", based on number of cases recognized among the susceptible camp populations (those who were not known to have been previously infected). Persons in whom infections were previously recognized were excluded from the susceptible population in an attempt to obviate the likelihood of infection rates being influenced by resistance to infection that might have been acquired through previous infections, or by recurrences that might not be differentiated from initial infections. From the inception of recording malaria cases in January, 1942, through August, 1942, malaria cases were recorded by the contractor's physician and are based on clinical evidence only. From September, 1942,

to September, 1943, inclusive, malaria cases are based on microscopic blood examinations. Chart V, Figure 2, indicates the infection rate among the susceptible camp population in area "B". Prior to December, 1941, positive cases were determined by the contractor's physician, based on clinical evidence, and from December, 1941, to September, 1943, inclusive, positive cases were determined by microscopic blood examinations. These data indicate that in area "A" in which malaria control was begun soon after the camp was populated, malaria did not occur to any great extent, whereas, in area "B", which was populated several months before control activities were instituted, the disease reached the alarming proportion of one person infected out of every three living in the camp in December, 1941. After malaria control was established, however, the incidence of malaria declined rapidly and was soon under control. As indicated by Earle (1939), it might be expected that the summer months of June, July and August, 1942 and 1943, as well as the winter months of November and December, 1942, would again threaten the camp population with outbreaks of malaria. However, no evidence of such a threat is discernible in charts I and V, suggesting that not only can the disease be brought under control by employing the established measures, but can be kept under control in an area that has been highly endemic.

Collection of Adult *An. Albimanus*: Charts II and III show *An. albimanus* that were collected in natural resting places and in animal bait traps in area "A"; charts V and VI show the same for area "B". Rainfall records for each of the two areas are also shown. Pronounced general decreases in adult populations, as measured by these methods, are apparent after control measures became effective. However, considerable increases occur during periods of heavy rainfall. These increases are apparent in collections made in natural resting places as well as in those made in animal bait traps. However, the numbers taken in animal bait traps are much greater than those collected in resting places. It is, therefore, considered that the use of animal bait traps affords the more reliable expression of adult population. Moreover, in order to find *An. albimanus* in tents, buildings, and other resting places, inspections must be made very early in the morning. As shown by Weathersbee and Bohart (1944), members of the species seek cover immediately after sunrise. Consequently, observations made at a later hour might result in an erroneous impression of the prevalence of the species within an area.

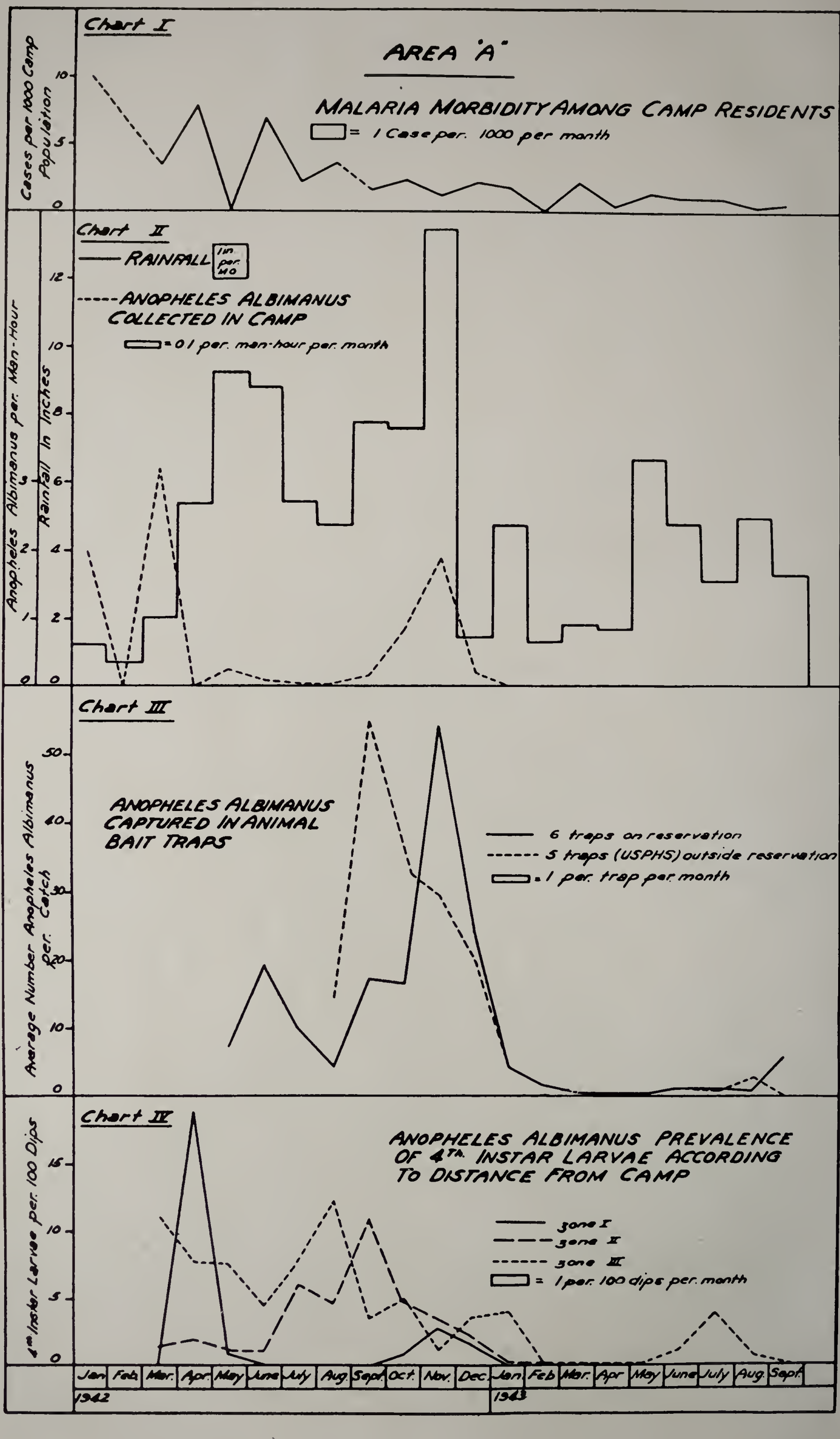
Chart I
AREA "A"
MALARIA MORBIDITY AMONG CAMP RESIDENTS
= 1 Case per 1000 per month
Cases per 1000 Camp Population
Chart II
RAINFALL (in per MO)
ANOPHELES ALBIMANUS COLLECTED IN CAMP
= 0.1 per man-hour per month
Anopheles Albimanus per Man-Hour
Rainfall in Inches
Chart III
ANOPHELES ALBIMANUS CAPTURED IN ANIMAL BAIT TRAPS
6 traps on reservation
5 traps (USPHS) outside reservation
= 1 per trap per month
Average Number Anopheles Albimanus per Catch
Chart IV
ANOPHELES ALBIMANUS PREVALENCE OF 4TH. INSTAR LARVAE ACCORDING TO DISTANCE FROM CAMP
zone I
zone II
zone III
= 1 per 100 dips per month
4th Instar Larvae per 100 Dips
Jan Feb Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan Feb Mar. Apr. May June July Aug. Sept.
1942
1943

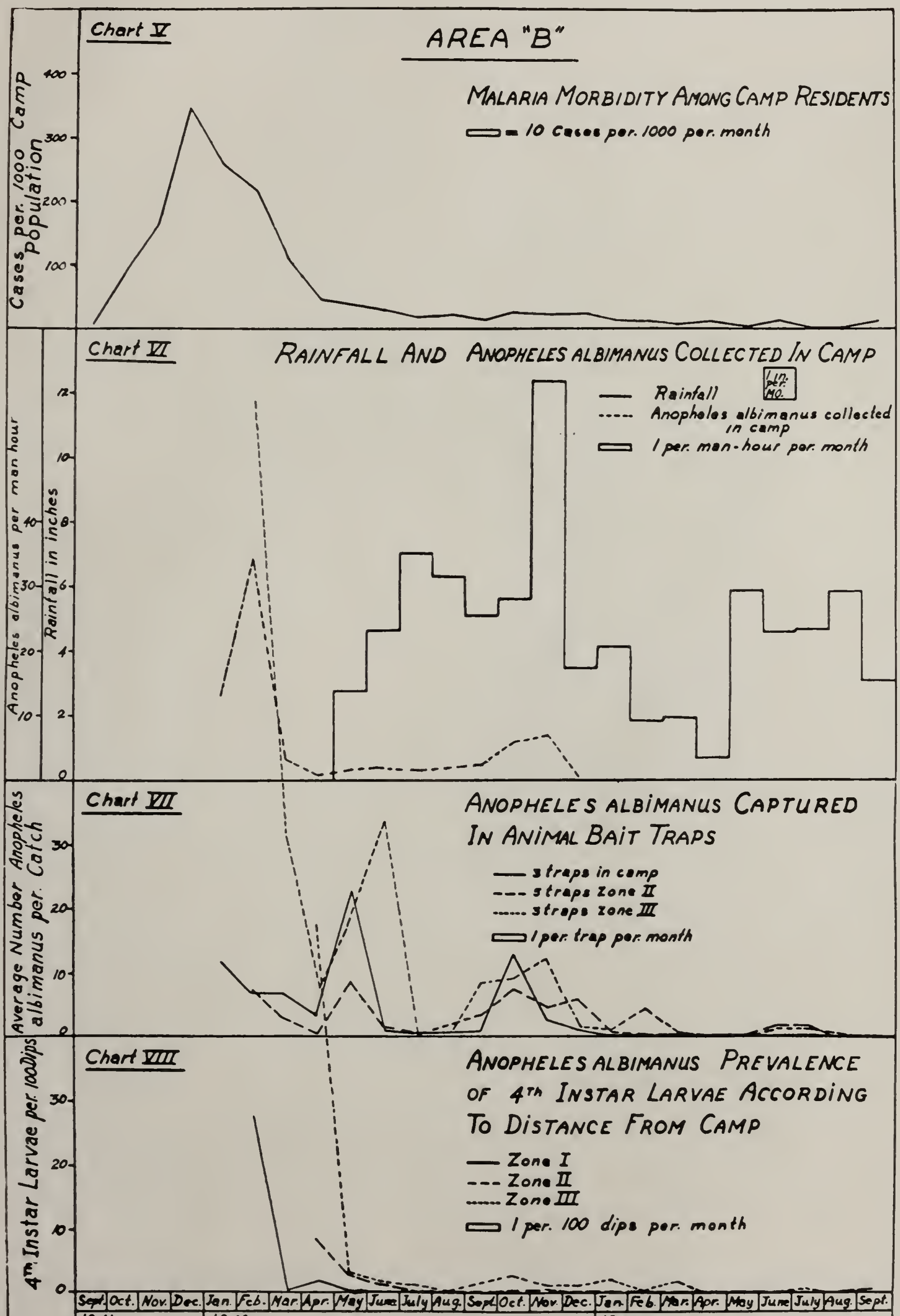

Chart V
AREA "B"
MALARIA MORBIDITY AMONG CAMP RESIDENTS
= 10 Cases per. 1000 per. month
Cases per. 1000 Camp Population
Chart VI
RAINFALL AND ANOPHELES ALBIMANUS COLLECTED IN CAMP
Rainfall
1 in. per. MO.
Anopheles albimanus collected in camp
1 per. man-hour per. month
Anopheles albimanus per man hour
Rainfall in inches
Chart VII
ANOPHELES ALBIMANUS CAPTURED IN ANIMAL BAIT TRAPS
3 traps in camp
3 traps Zone II
3 traps Zone III
1 per trap per month
Average Number Anopheles albimanus per. Catch
Chart VIII
ANOPHELES ALBIMANUS PREVALENCE OF 4TH INSTAR LARVAE ACCORDING TO DISTANCE FROM CAMP
Zone I
Zone II
Zone III
1 per. 100 dips per. month
4TH Instar Larvae per 100 Dips
Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept.
1941
1942
1943

Density of *An. albimanus* as determined by the Prevalence of Fourth Instar Larvae: The prevalence of fourth instar larvae was used to measure the effectiveness of control measures. In charts IV and VIII, the number of fourth instar *An. albimanus* collected per 100 dips in each area is shown for each month. It will be seen that in each area the density of fourth instar larvae declined rapidly in the one mile zone, in which control measures were first employed. Control measures were extended into the second and third mile zones after situations nearer camp were corrected and brought under control. In area "A", the net result was a gradual diminution in the prevalence of larvae in the outer zones, as control measures were extended into them. In area "B", Zone III was rapidly brought under control by increasing the salinity of the fresh water ponds in two sections.

Comparison of Adult and Larval Densities: Under natural conditions, it might be expected that larvae would become more prevalent during periods of heavy rainfall than at other times. Under the controlled conditions with which this report deals, the prevalance of larvae is sometimes greater during rainy periods than during dry periods,. However, the peaks of larval density do not always coincide with the peaks of rainfall. In regard to the prevalence of adults, it is seen that it rises and falls very much in accord with the increases and decreases in rainfall. These increases in adult prevalence without corresponding and comparable increases in fourth instar larvae strongly suggest an increase longevity of adults during prolonged periods of high humidity accompanying rainy weather rather than an increase primarily in production.

Microscopic Blood Film Examinations: Periodic surveys were made on samples of the populations with which this report deals. Thick film stained with Giemsa's stain were examined by laboratory technicians specially trained by the Officer-in-Charge of malaria control. Data pertaining to these surveys are summarized in Tables IV and V. Table IV shows the findings of surveys in each area, according to residence within the camp and non-residence. In area "A", it is seen that, based on these results, malaria did not become established among camp residents to any great extent and was at all times almost negligible. In regard to non-residents, while the rate of infection decreased in general, it always remained higher than in camp residents.

In area "B", at the time control measures were started, a survey revealed the alarming infection rate of 28.2 per cent among camp residents and 39 per cent among non-residents. Subsequent sur-

veys, however, failed to reveal infections among camp residents, and showed a decided decrease in the rates for non-residents. As this area is situated on a small island, it is possible for the local health agencies to practice control measures in and around all centers of population. It is considered unlikely that the decrease among non-residents is entirely attributable to natural conditions, but is largely the result of cooperative efforts of the Navy and local health agencies.

In Table 5, the survey results are shown for camp residents according to nativity. In area "A", it is again evident that the rate among both continental and native inhabitants was at all times quite low. In area "B", however, these rates were 14.6 per cent for continentals and 36.1 per cent for natives in December, 1941. Subsequent surveys, however, failed to demonstrate the presence of infections.

Table 4.—Microscopic Blood Film Examinations of Personnel

Month	Area A								
	Camp Residents			Non-Residents			Total		
	No. Exam.	No. Pos.	% Pos.	No. Exam.	No. Pos.	% Pos.	No. Exam.	No. Pos.	% Pos.
Feb. 1942	33	0	0.0	325	10	3.1	358	10	2.8
June	129	2	1.5	688	11	1.6	817	13	1.6
December	672	1	0.2	301	4	1.4	973	5	0.5
April 1943	879	6	0.7	—	—	—	879	6	0.7
Month	Area B								
Dec. 1941	131	37	28.2	59	22	39.0	190	59	31.1
June 1942	241	0	0.0	681	63	9.3	922	63	6.8
Dec.	403	0	0.0	595	17	2.9	998	17	1.7
July 1943	125	0	0.0	228	2	0.9	353	2	0.6

Table 5. — Microscopic Blood Film Examinations of the Camp Residents According to Nativity

Month	Area A					
	Continental			Native		
	No. Exam.	No. Pos.	% Pos.	No. Exam.	No. Pos.	% Pos.
Feb. 1942	33	0	0.0	—	—	—
June	129	2	1.5	—	—	—
December	603	1	0.2	69	0	0.0
April 1943				879	6	0.7
Month	Area B					
Dec. 1941	48	7	14.6	83	30	36.1
June 1942	149	0	0.0	92	0	0.0
December	205	0	0.0	198	0	0.0
July 1943	125	0	0.0	—	—	—

Table 6, showing the identification of malaria parasites according to species and according to occurrence in continentals and in natives in both areas, is presented to show the relative prevalence of the different species and the decrease in relative prevalence of *P. falciparum* that occurred during the period covered in this report. It further shows that the three recognized species of human malaria are present in this area, but that *Plasmodium malariae* is relatively unimportant.

Table 6. — Microscopic Blood Film Examination of Personnel Identification of Malaria Parasites According to Species

Month	AREA "A"				AREA "B"				
	Continental		Natives		Continental		Natives		
	P.v.	P.f.	P.v.	P.f.	P.v.	P.f.	P.v.	P.f.	P.m,
Dec. 1941	----	----	----	----	2	6	29	36	1
February 1942	0	0	3	7	----	----	----	----	----
June 1942	2	0	5	6	0	0	37	29	0
December 1942	0	1	4	0	0	0	13	4	0
April 1943	----	----	1	5	----	----	----	----	----
July 1943	----	----	----	----	0	0	2	0	0

P. v. Plasmodium vivax *P. f. Plasmodium falciparum*
P. m. Plasmodium malariae

Summary

From the data presented, it may be seen that by employing the established malaria and mosquito control practices, an outbreak of malaria which threatened the curtailment of naval construction activities was rapidly brought under and kept under control in a highly malarious area in which *An. albimanus* were numerous. The population of *An. albimanus* was rapidly decreased, and the decline in malaria was measured by periodic blood suveys of the human populations involved. The normal cycle o fincrease and decrease in the incidence of malaria was interrupted, and normally expected seasonal increases of the disease failed to occur.

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PLANNING FOR MALARIA PREVENTION ON POSTWAR IMPOUNDMENTS*

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The artificial impoundment of waters has in recent years assumed a position of more and more significance with respect to the national public health and well-being. The period between 1880 and 1920 constituted an era of drainage in the United States. Since that time there has been a growing tendency toward impoundage.

Many governmental agencies both federal, state and local, are planning artificial lakes for navigation, flood control, hydroelectric development, soil conservation, irrigation, etc., incorporated in which are comprehensive plans for the use of such lakes for recreational and wildlife purposes. This trend, already established, may lead to an era of impoundage, creating attendant problems in public health particularly with respect to malaria control.

As a matter of fact several years ago Mr. Joseph A. LePrince, former sanitary Engineer Director, U. S. Public Health Service, an authority on malaria control engineering, made this prediction: "An increase in the incidence of malaria may be experienced not only in the southern states but also in the northern section of the United States unless adequate steps are taken to control mosquito breeding on artificailly created lakes."

Awareness of Problem and Factors Contributing to Problem

The present interest in this work is due to the growing realization on the part of the authorities concerned that proper preparation and maintenance of artificial lakes play vital roles in the prevention and control of malaria transmission. This interest is emphasized by several factors.

In the South repeatedly, and occasionally in the North, outbreaks of malaria have occurred in populations residing within mosquito flight range of improperly prepared artificial lakes. Most newly created, but not properly prepared lakes, in the South and many in in North produce *Anopheles quadrimaculatus* mosquitoes in large numbers and lack only the presence of carriers of malaria to create a serious problem. Recognizing the danger to public health several State Boards of Health have promulgated regulations while

* Presented at the meeting of the National Malaria Society, Cincinnati, Ohio, 13 November, 1945.

others have been instrumental in securing the passage of laws governing the impounding and maintenance of waters.

In past years numerous small outbreaks of malaria have been reported around impoundages in sections of the country otherwise free of the disease. Such outbreaks as a rule were adequately explained by the presence of carriers of chronic malaria found among migrant railroad repairmen, agricultural workers and other imported labor. A similar situation but with much greater potential hazard now exists in the nationwide demobilization of thousands of veterans returning from duty in the malarious areas of the earth, a hazard which will be amplified by either temporary or permanent residence in the vicinity of improperly prepared or maintained water impoundments.

Steps Take to Meet Ploblem

To partially combat these acknowledged hazards, in March 1945, an agreement was drawn up between the Office of the Chief of Engineers, U. S. Army, and the Office of the Surgeon General, U. S. Public Health Service, in which it was agreed that the Public Health Service in cooperation with the U.S.E.D. and the request of the U.S.E.D., would make reconnaissance surveys of all proposed or existing reservoir projects. The report of these surveys to the U.S.E.D. would include recommendations regarding proper preparation and maintenance procedures on impounded waters and would cover the need, type and extent of (malaria control) measures necessary to prevent or correct conditions favorable for malaria transmission. To date dequests have been received for malaria surveys on 140 impoundages located in 33 states.

The Office of Water and Sanitation Investigations of the U. S. Public Health Service, located in Cincinnati, Ohio, was designated to receive requests for the desired surveys from the U.S.E.D. The Impounded Water Section of the Office of Malaria Control in War Areas, Atlanta, Georgia, was designated to make the necessary studies of the impoundments and to prepare recommendations regarding appropriate prevenative or corrective malaria control measures based on such studies.

Initially it was not planned to make studies of reservoir sites in northern or eastern states. However, since all artificial lakes may produce malaria vectors in some numbers and since malaria carriers are now numerous and widespread in the United States it was decided to make studies of reservoirs in all sections of the country, the scope of the study being determined by the problem peculiar to each site.

Purpose of Impounded Water Studies and Factors Involved

Briefly the primary purpose of impounded water studies is to determine the measure necessary for the proper preparation and maintenance of water impoundments. Such measures may then be incorporated in the construction, operation and maintenance plans, thus preventing or correcting, and controlling conditions favorable to the production of malaria carrying mosquitoes and the transmission of malaria.

The factors having a direct bearing on malaria control are so numerous, so variable and generally so interrelated as to make it impossible to develop a standardized plan which would be applicable to all reservoir sites. It is possible to outline in a general way the major factors which influence control. These factors include the amount of periods of rainfall, frequency offloods, the operation of the reservoir, the extent and location of residual pools of water in the zone of fluctuation, the type, density and distribution of timber in the reservoir area, the human population density within mosquito flight range of the impoundage, the type of housing and the type and location of wildlife refuges and recreational areas with respect to mosquito breeding and population areas.

Mechanics of Study of Reservoir Sites:

A. *Brief Outline of Major Phases of Such a Study.*

All reservoir sites are studied but more detailed and comprehensive surveys are made in the states where malaria is still endemic. Studies are made jointly by the U. S. Public Health Service and the respective State Boards of Health, with the active cooperation of the U.S.E.D.. The concurrence of the State Board of Health is secured prior to submission of the recommendations to the U.S.E.D.

The studies include a careful review of construction, operation, and maintenance plans, of epidemiological and climatological data, and of entomological and engineering field inspection data. On the entomological field inspection of the reservoir, data are secured on mosquito breeding in the vicinity of the reservoir prior to impoundage. These data are necessary to provide a baseline for evaluating subsequent mosquito breeding and malaria conditions. They are also vital in planning the maximum utilization of the reservoir for recreational and wildlife purposes with due regard to public health. Finally through preventive planning, such data would appreciably reduce the cost of malaria control.

On the engineering field inspection, data are gathered on the physical characteristics of the reservoir area, the operation of the

reservoir, the hydrology of the watershed and other technical information affecting plans for malaria control.

The integration and analysis of the various pertinent data thus secured provide the basis for recommendations to the U.S.E.D. regarding proper preparation and maintenance relative to malaria control methods necessary for a particular impoundage. These recommendations are then incorporated by the U.S.E.D. in the plans and specifications for the construction, operation and maintenance of the development.

B. *Preparation and Maintenance Measures Usually Recommended.*

1. *Clearing*: The clearing of the basin is of paramount importance but requirements for this phase of the program vary for each reservoir site. The majority of the reservoirs now under consideration are multiple purpose ones designed primarily for flood control and secondarily for navigation or power development. On such impoundments the timber and underbrush must be completely cleared from the entire reservoir basin up to and including a few feet above the conservation pool elevation. The portion of the clearing above the conservation pool elevation permits a more favorable fluctuation schedule without interference with the development of power.

Clearing operations should be so scheduled as to be completed just prior to impoundage. Coppice or other secondary growths which develop while the clearing is in progress should be removed in a rapid operation just before closure of the reservoir in order to prevent re-growth.

In the event that floods occur only during winter no clearing may be necessary in the zone between the conservation pool elevation and the flood pool elevation. However, if floods occur during the growing season it may be necessary to remove and destroy all trees and underbrush in this zone which cannot withstand such flooding.

2. *Fluctuation*: A proper operating schedule for the reservoir is of utmost importance, increasing the effectiveness of the malaria control measures and decreasing the cost; both to a marked degree. It is also very important that the reservoir be initially filled during the fall, winter or spring months.

The best operating schedule calls for accumulating a high spring level (with a surcharge if possible), then at the beginning of the moquito breeding season effecting a sudden sharp drop to the elevation set as a limit for clearing operations to strand drift and flotage and following with a uniform recession during the mosquito

breeding season. Favorable operating schedules have been found practicable on the great majority of the impoundments studied.

3. *Drainage*: The installation of adequate drainage for residual pools lying in the zone of fluctuation is generally recommended. In sparsely settled areas only the pools within mosquito flight range of focal points of people may need drainage. The policy of several District Offices of the U.S.E.D. is to install such drainage regardless of malaria control requirements to prevent the stranding and destruction of fish due to the drying up of pools.

4. *Aquatic Plant Removal*: In the preliminary field inspection the location of any aquatic plants, which may hamper the operation of the reservoir or may be favorable to mosquito production, is noted and recommendations are made concerning the removal and reoccurrence of such plant life.

5. *Drift and Flotage Removal*: Where a spring surcharge is practicable the majority of debris and flotage can be stranded at a high elevation and cheaply disposed of by machinery.

6. *Larvicidal Operations*: The need for larvicidal work is greatly reduced on properly prepared lakes. However, a certain amount of larviciding may be necessary in specific areas such as flooded vegetated shallow areas near centers of population or recreational developments containing housing facilities. The preferred larvicides for impoundments have been Paris green and Diesel oil. A new insecticide, DDT, may soon come into general use, and promises to make larviciding easier, better and cheaper. The use of a water-oil power unit is usually recommended as this type of equipment has proved extremely effective for breaking up mats of flotage usually found on new lakes and generally results in more efficient and economical control of mosquito breeding.

7. *Periodic Entomological Inspection of Impounded Areas* In most cases the respective State Board of Health will assume responsibility for periodic entomological inspections of the reservoir site and territory adjacent. This will enable them to keep abreast of changing mosquito breeding conditions and secure a baseline to which to measure the effects of the impoundage and check on the effectiveness of the mosquito control measures.

8. *Creation of a Malaria Control Unit*: It is urgently recommended that the U.S.E.D. provide qualified superintendents, foremen, and entomological inspectors to supervise malaria control units for carrying out malaria control measures on the respective impoundments. If no experienced personnel are available the State Boards of Health will usually assist in training personnel suitable for this work.

Coordination and Cooperation with Other Governmental Agencies, Federal and State.

One of the most important phases of the entire program is that it invites the cooperation of other federal and state governmental agencies through coordination of planning thus permitting the incorporation of proper malaria control measures in project plans and specifications. This is illustrated in the development of recreational and wildlife areas. Certain types of wildlife refuges favoring malaria mosquito production are located only in sparsely populated sections at least two miles from towns, cities, recreational areas with housing or other population centers. Officials of two Districts of the U.S.E.D. have already indicated that locations for recreational areas are being selected where mosquito breeding is relatively light and where the cost of control in future years will not be excessive. These areas will be made as attractive as possible in order to draw the general population into them. The plans also call for the installation f safe water supplies and satisfactory methods of sewage disposal in accordance with the standards of the respective State Boards of Health and for the construction of all-weather access roads into these favorable camping areas.

This attention to the proper location and development of recreational areas is of the greatest importance in planning for malaria control and the officials of the District Offices are to be commended for their far-sighted approach.

Summary of Reporting of Studies

Following the completion of studies of the various reservoirs, survey reports incorporating definite recommendations are submitted to the U.S.E.D. On those impoundments located in the deep South both a preliminary survey report and a more detailed comprehensive final survey report are made. The preliminary survey report gives important data compiled from a brief inspection. A final survey embracing more detail is prepared on reservoirs where malaria is still endemic.

In sections of the country where malaria is not endemic at present a reconnaissance report is submitted. This report is not as complete as the final survey report but is more comprehensive than the preliminary report.

Conclusions

The construction of artificial lakes constitutes an important postwar activity. Lakes which are properly constructed will become valuable national assets contributing both to the real wealth of the nation and to the health and happiness of its citizens.

Every effort should be made to promote such activities and to develop techniques permitting their maximum utilization. The purpose of these impounded water, malaria investigational studies is to contribute the most practical recommendations possible for the prevention of malaria transmission, to further develop techniques of control, and to assist in the coordination of planning by the federal and state agencies concerned, thus promoting the national well-being through the cooperative effort.

EXTENT OF RESEARCH IN THIS COUNTRY

American Cynamid Company, Stamford, Connecticut

(*Dr. Sterling Brackett*)

Testing of antimalarial drugs against sporozoite-induced infections of *Plasmodium gallinaceum* in chickens has constituted the main line of research. Correlative studies on physiology of the parasite are also being carried on.

Station for Malaria Research (Florida State Health Department, Rockefeller Foundation), Tallahassee

(*Dr. Mark F. Boyd*)

A wide variety of studies have been carried out since 1931, the majority of which may be designated as dealing with the host-parasite relationship.

Human malarias are studied, the patients being available at the Florida State Hospital at Chattahoochee, where a Malaria Therapy Service is maintained. All three classical species of human malaria parsites are maintained: about a dozen strains of *Plasmodium vivax,* a similar number of strains of *P. falciparum,* and about a half dozen strains of *P. malariae* have been studied during the time the station has been in operation. The McCoy strain of *vivax* has been passed through 92 serial passages in mosquitoes. Other strains and species have been maintained by mosquito passage for various shorter periods.

The colony of *Anopheles quadrimaculatus* has been maintained continuously for 15 years. *A. punctipennis* and *A. crucians* were cultivated for a time but are not being used at present.

Numerous papers reporting the studies carried out at this station have appeared in the American Journal of Hygiene, the American Journal of Tropical Medicine, and the Journal of the National Malaria Society over a period of years.

This laboratory has not carried out any O.S.R.D. studies.

University of North Carolina, School of Medicine, Chapel Hill

(*Dr. James C. Andrews*)

Interest has been directed chiefly at the relationship between nutritional deficiencies and drug metabolism. Quinine is being used for this study, at present in the white mouse only. It is planned later to work with this drug in malaria-infected and normal ducks, both with and without nutritional deficiencies.